Role of Potassium in Water Stress Management in Dry land Agriculture

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This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.

Introduction

- Crop production in the world has made a remarkable step forward since the sixtees enabling to feed its steadily increasing population although the area of arable land remained almost the same.

- An analysis of the nutrient balances (Syers et al. 2001) for the period 1960-1998 for six Asian countries, indicated an overall annual K deficit of about 11 m t of K, which is 250 per cent more than the current K fertilizer use.

- Recent estimate of nutrient balances in world soils indicated the largest negative K balance in Asia followed by Africa and positive K balances in America and Europe (FAO 2003).

- In India, a considerable progress was made over the years in increasing the food grain production reaching a record level of 231 mt in 2007-08, yet it will require about 7-9 mt additional food grains each year if the rising population trend continues.

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Introduction

- Among the essential plant nutrients, potassium assumes greater significance since it is required in relatively larger quantities by plants.
- Besides increasing the yield, it improves the quality of the crop produce and improves N and P use efficiency.
- Among soil fertility problems, potassium deficiency is one of the emerging nutritional constraints for increasing productivity levels of dryland crops (Srinivasa Rao and Vittal 2007; Srinivasa Rao and Venkateswarlu 2009).
- Potassium nutrition has special significance in dryland crops as its optimum K nutrition is associated with crop tolerance to water stress condition, which is a common feature of dryland agriculture.




Introduction

•Two-thirds of the cultivated area in India is under rainfed farming.

•Rainfed agriculture support 40% of India's human population and two-thirds of the livestock.

• Ninety percent of the coarse cereals, 90% grain legumes, 80% oilseeds and 65% of cotton are grown in rainfed regions.

•However, rainfed areas suffer from a number of crop production constraints. Among them, low soil organic carbon, poor soil fertility, frequent droughts are important factors which determine the productivity levels of dryland soils.

•As the food production increased with time, the number of deficient elements in Indian soils and crops also increased.




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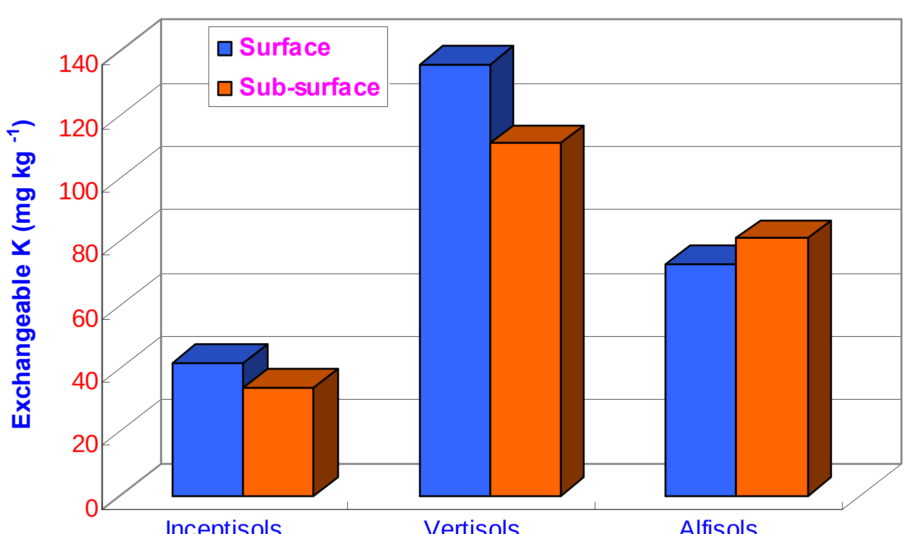
Potassium status in different agroecological regions of India

Agroecological region and states covered	Climate/Soil	Exchangeable K	Non exchangeable K
Region 2 Gujarat, Rajasthan, Harayana	Hot arid-black and alluvial	L-H	L-H
Region 3 A.P	Hot semi arid- red soils	L-M	L-H
Region 4 U.P., Rajasthan, Gujarat, M.P.	Hot semi-arid a-Alluvial	M-H	H
Region 5 Rajasthan, Gujarat, M.P.	Hot semi-arid medium-deep black	H	M-H
Region 6 Maharastra, Karnataka, A.P.	Hot semi-arid Medium-deep black	H	M-H
Region 7 A.P.	Hot semi-arid Red and black	L-H	L-M
Region 8 Tamil Nadu, Karnataka, A.P.	Hot semi-arid Red loamy	M	L
Region 9 U.P.,Uttaranchal, Bihar,	Hot sub-humid alluvial	M	M-H
Region 10 M.P.	Hot sub-humid black	H	M-H
Region 11 M.P. Maharastra	Hot sub-humid Red & yellow	H	M-H
Region 12 Jarkhand, M.P. Chattisgadh	Hot sub-humid Red & Latoritic, black	L-M	L
Region 13 Orissa, Jarkhand, Chattisgadh	Hot sub-humid Alluvial	M-H	L-H
Region 14 H.P, J&K, Punjab	Humid –Acidic alluvium	L-M	L-M
Region 15 West Bengal, Sikkim, Assam, Arunachal Pradesh	Hot-Sub humid-Terai acid soils	L-H	L-H
Region 17 Meghalaya	Per humid-red and lateritic	L-H	M-H
Region 18 A.P., T.Nadu, Orissa	Hot semi arid –coastal light	L-H	L-H
Region 19 Kerala	Per humid –lateritic	L-H	Low
Region 20 Andaman-Nicobar	Per humid-red loamy	M	M

L: low; M: Medium; H: High

Subba Rao and Srinivasa Rao(1996)

Exchangeable K in different soil types of India



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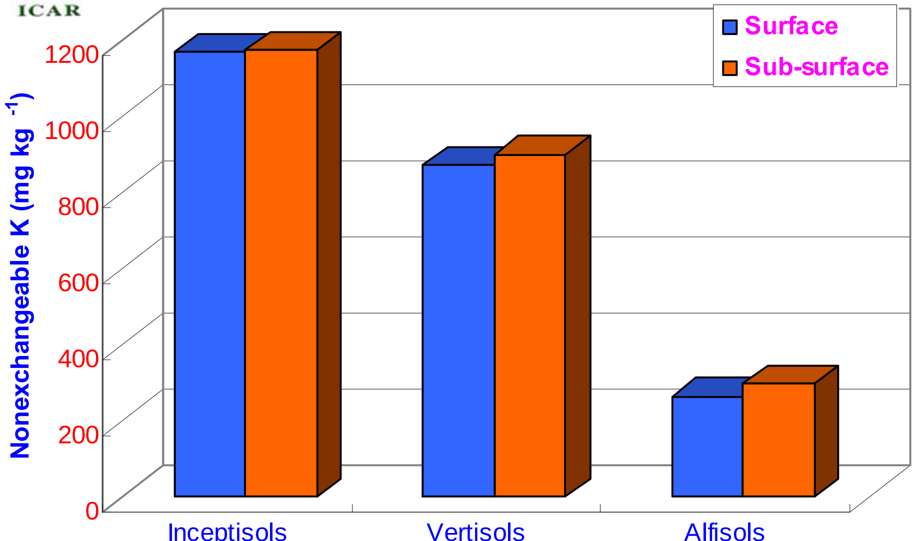
Nonexchagneable K in different soil types of India

(Source : Srinivasarao and Vittal 2007)



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K Deficiency Symptoms

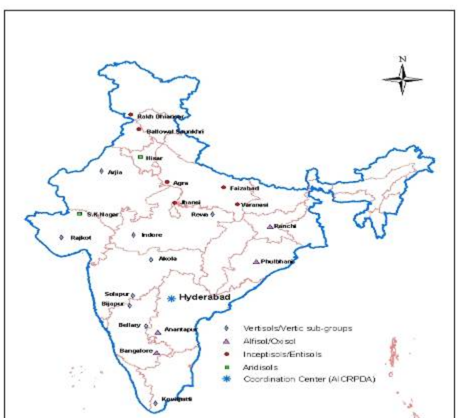

Figure 1: Soil sampling sites
All India Coordinated Research Project for Dryland Agriculture in India

Profile Location in India

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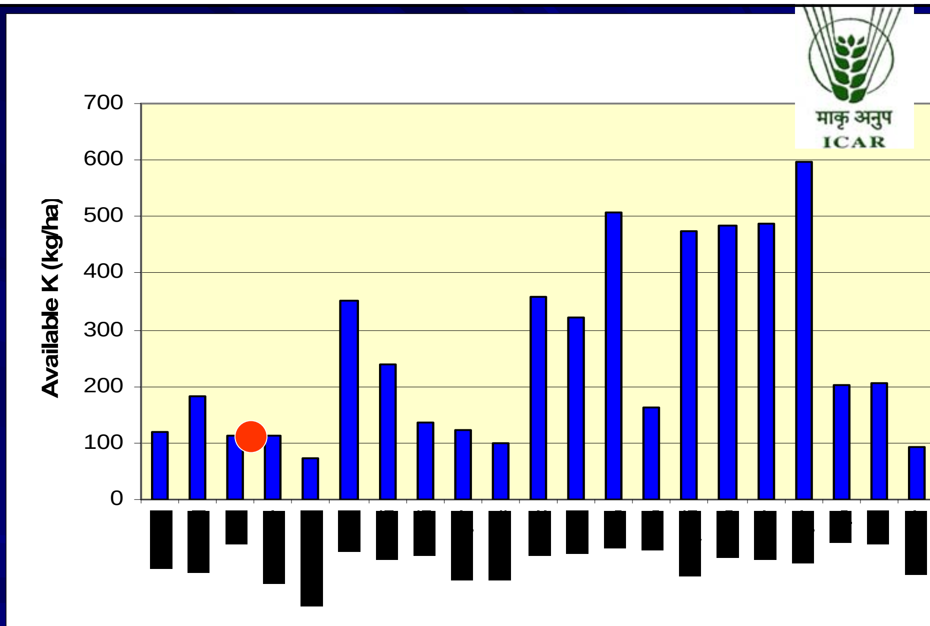

Available K status in different soil types under rainfed production systems of India (Source:Srinivasarao *etal* (2007)

Multi-nutrient Deficiencies in Different Rainfed Regions of India

Location	Limiting Nutrient (Low/Deficient)
Varanasi	N, Zn, B
Faizabad	N
Phulbani	N, Ca, Mg, Zn, B
Ranchi	Mg, B
Rajkot	N, P, S, Zn, Fe, B
Anantapur	N, K, Mg, Zn, B
Indore	-
Rewa	N, Zn
Akola	N, P, S, Zn, B
Kovilpatti	N, P
Bellary	N, P, Zn, Fe
Bijapur	N, Zn, Fe
Jhansi	N
Solapur	N, P, Zn
Agra	N, K, Mg, Zn, B
Hisar	N, Mg, B
SK.Nagar	N, K, S, Ca, Mg, Zn, B
Bangalore	N, K, Ca, Mg, Zn, B
Arjia	N, Mg, Zn, B
Ballowal-Saunkri	N, K, S, Mg, Zn
Rakh-Dhiansar	N, K, Ca, Mg, Zn, B

Srinivasarao and Vittal (2007)

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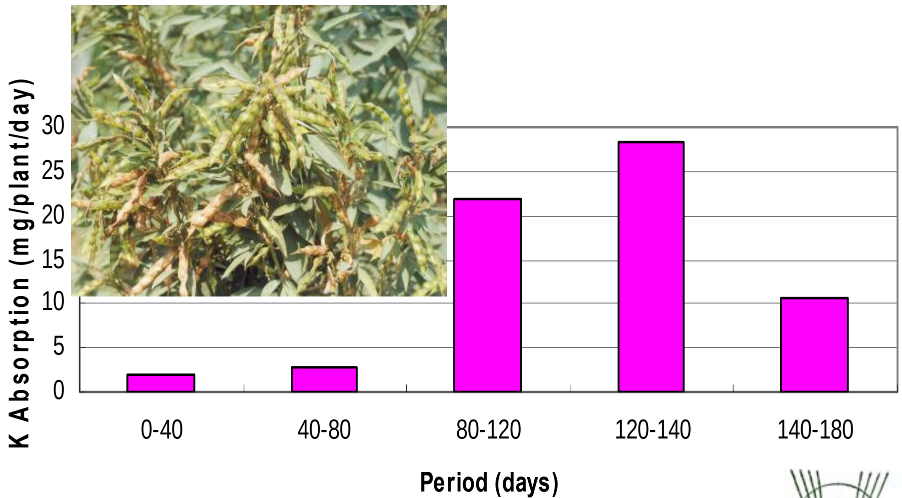
Nutrient uptake in long-term fertilizer experiments under intensive cropping systems in India

Cropping	Soil type	Yield (t/ha)	Nutrient uptake (kg/ha/year)			
			N	P	K	Total
Maize-wheat-cowpea (F)	Inceptisols	6.8+0.6*	240	45	250	535
Rice-wheat-jute fibre	Inceptisols	6.5+1.5	250	50	275	575
Maize-wheat-cowpea (F)	Mollisols	9.5+1.9	260	65	295	620
Rice-rice	Inceptisols	6.2	150	40	175	365
Soybean-wheat	Vertisols	6.3	285	44	225	554
Soybean-wheat	Alfisols	4.2	220	35	170	425
Fingermillet-maize	Alfisols	6.5	210	42	215	467
Fintermillet-maize	Inceptisols	6.5	245	40	270	555
Ground-wheat	Alfisols	2.9	106	18	65	189
Sorghum-sunflower hybrids	Verisols	2.9	89	42	117	248

Source: Swarup and Wanjari, 2001; * F: Fodder

Nutrient uptake of some important rainfed crops in India (Source: Srinivasarao and Venkateswarlu, 2009)

Crop	Produce	kg nutrient/tonne produce		
		N	P_2O_5	K_2O
Sorghum	Grain	22.4	13.3	34.0
Pearl millet	Grain	42.3	22.6	90.8
Rice	Grain	20.1	11.2	30.0
Chickpea	Grain	46.3	8.4	49.6
Groundnut	Grain	58.1	19.6	30.1
Soybean	Grain	66.8	17.7	44.4
Sunflower	Grain	56.8	25.9	105.0
Cotton	Seed	44.5	28.3	74.7



Rate of K absorption by pigeonpea

Fertilizer consumption ratios in India

Consumption (kg/ha)	1960-61	1970-71	1980-81	1990-91	2001-02	2004-05	2005-06
N	1.4	9.0	21	43	59	62	67
P_2O_5	0.4	3.3	7	17	23	24	27
K_2O	0.2	1.4	4	7	9	11	13
Total	2	14	32	68	90	97	107
P_2O_5:K_2O (N=1.0)	0.37:0.16	0.37:0.16	0.33:0.17	0.40:0.17	0.37:0.14	0.39:0.18	0.40:0.18

FAI (2006)

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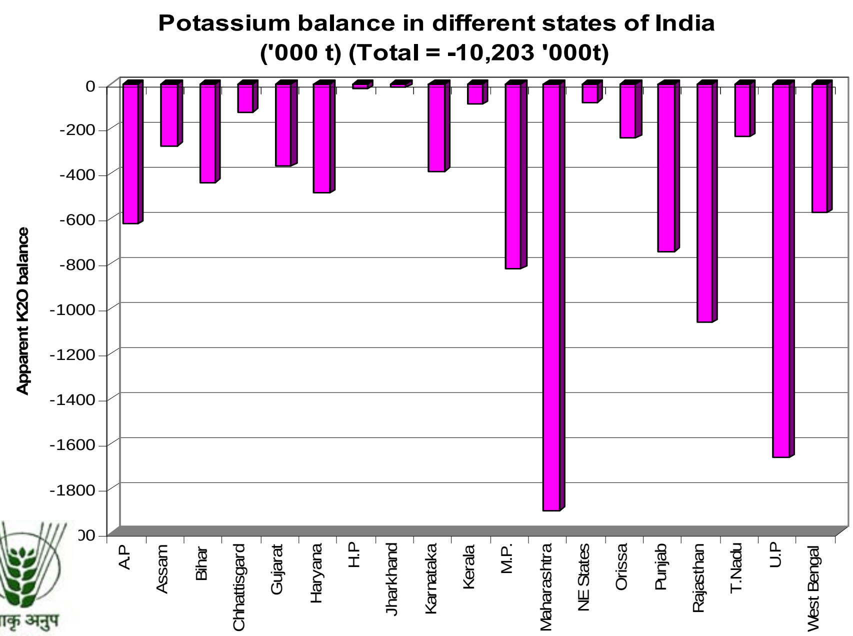
Critical areas of imbalance in fertilizer consumption

Sl No.	Agro-ecological region	N	P_2O_5	K_2O	N: P_2O_5	Cropping/ Cropping system	N	P_2O_5	K_2O	N: P_2O_5
4	N_8D_2	37.0	9.6	1	3.6	Rice-wheat	205.0	47.0	1	4.35
9	N_8C_3	23.5	4.7	1	5.0	Maize-wheat	34.0	4.9	1	3.61
14	O_8C_4	17.3	3.4	1	5.1	Rice-pulse	7.4	2.1	1	3.47
15	$A_{15}C_4$	14.5	2.5	1	5.7	Potato-wheat	14.5	2.5	1	5.73
18	D_8A_5	11.4	2.9	1	3.9	Sugarcane	21.1	4.2	1	5.00

Source: Swarup and Ganeshmurthy, 1998.



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Mechanism of water stress management with optimum K nutrition

@ Better root growth

@ Stomatal movement: K fed plants quick to respond in stomatal closure under water stress conditions

@ Increase water use efficiency

Effect of water stress and K^+ supply on net photosynthesis rate in wheat leaves

(Source : Sen Gupta et al., 1989)

K^+ application (mM)	Photosynthesis (µmol CO_2 m^{-2} S^{-1})		
	Water stress in leaves		
	Low	Mild	Severe
0.2	38	11	2
2.0	47	42	21
6.0	46	45	28

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Effects of potassium deficiency and water stress on the rate of photosynthesis in tomato leaves

(Source: Behboudian and Anderson, 1990)

Treatment		Leaf water potential (MPa)	Photosynthesis(µ mol m^{-1} s^{-1})
Potassium	Irrigation		
+K	Watered	-0.46	6.47
+K	Stressed	-1.47	2.50
-K	Watered	-0.40	3.97
-K	Stressed	-0.59	2.44

Effect of potassium on proline content [µg g^{-l} (d.m.)] of leaves and nodules in *Vigna radiata* under drought and rehydration (Source: Nandwal et al. 1998).

	Leaves control	Stress	Recovery	Nodules control	Stress	Recovery
K0	129	1989	400	488	6204	1132
K1	123	2696	546	455	6013	1022
K2	150	2436	565	432	5368	1041

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Effect of three levels of potassium nutrition on selected growth parameters of *Hibiscus rosa-sinensis* L. Cy. Leprechaun, grown under drought stressed and controlled conditions

K supply (mM)	Root DM (g)	Shoot DM (g)	Leaf DM (g)	Relative growth rate (μg d^{-1})	Root: Shoot ratio (g g^{-1})	Leaf area (m^2)
Drought stressed						
0.00	4.5	54.1	16.3	12.89	0.083	0.281
2.50	7.3	68.9	18.9	12.96	0.104	0.273
10.00	8.9	78.1	20.4	12.98	0.114	0.314
Non-drought stressed						
0.00	2.2	58.0	18.2	12.91	0.040	0.312
2.50	6.6	95.6	29.2	13.07	0.067	0.4594
10.00	6.0	99.2	29.8	13.09	0.061	0.503

Effects of K and drought stress on midday leaf water relations of *Hibiscus rosasinensis* L. cv. Leprechaun during a 21-d drought stress period.

Time [d]/ K supply (mM)		Ψ_I	Ψ	Ψ_P
21	K_0	-1.50	-2.10	0.59
	$K_{2.5}$	-1.52	-2.23	0.71
	K_{10}	-1.61	-2.37	0.76

Egilla et al., 2005

ΨI = leaf water potential, Ψ̃ = leaf osmotic potential, ΨP = leaf pressure potential [Mpa)

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Effects of K and drought stress on midday leaf water relations of *Hibiscus rosa-sinensis* L. cv. Leprechaun during a 21-d drought stress period.

Time [d]	K supply (mM)		P_N	*E*	g_s	P_N/E
21	K_0		5.39	2.98	0.17	1. 92
	$K_{2.5}$		8.27	3.13	0.18	2.64
	K_{10}		6.04	1.98	0.16	2.95

Egilla et al. 2005

PN = net photosynthetic rate [µmol m-2 S-1], *E* = transpiration rate [mmol m-2 S-1], gs = stomatal conductance [mol m-2 S-1].

Chlorophyll (Chl) contents of two lines of pearl millet when 19 d-old plants were subjected for 30 d [varying K supply [235.0. 352.5. or 470.0 mg kg^{-1} (soil)] under well-watered or drought conditions

Parameter	Line	Well-watered			Drought-stressed		
		235.0	352.5	470.0	235.0	352.5	470.0
Chl a [g kg^{-1}(FM)]	ICMV94 133	0.120	0.220	0.290	0.210	0.250	0.310
Chi *b* [g kg"(FM)]	ICMV94 133	0.050	0.090	0.150	0.110	0.170	0.240
Chl a b	ICMV94 133	2.33	2.65	2.01	2.11	1.83	1.29

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Water relation parameters of two lines of pearl millet when 19 d-old plants were subjected for 30 d [varying K supply [235.0. 352.5. or 470.0 mg kg^{-1} (soil)] under well-watered or drought conditions

Parameter	Line	Well-watered			Drought-stressed		
		235.0	352.5	470.0	235.0	352.5	470.0
Water potential [-MPa]	ICMV94 133	0.98	1.12	1.3 0	1.98	2.02	1.96
Osmotic potential [-MPa]	ICMV94 133	1.07	1.24	1.51	2.19	2.25	2.25
Pressure potential [MPa]	ICMV94 133	0.090	0.125	0.210	0.288	0.306	0.300

Effect of potassium on water and osmotic potentials [-MPa] and relative water content [%] of leaves and nodules in *Vigna radiata* under drought and rehydration.

K (mM/dm3)		Water potential			Osmotic potential			RWC		
		Control	Stress	Recovery	Control	Stress	Recovery	Control	Stress	Recovery
K_0	Leaves	0.55	0.84	0.67	1.34	1.55	1.47	80.98	72.31	78.15
	Nodule				1.21	2.34	1.72	89.50	65.77	80.04
K_1	Leaves	0.47	0.78	0.53	1.30	1.76	1.37	84.22	74.6	82.20
	Nodule				1.24	2.66	1.73	92.52	67.46	84.40
K_2	Leaves	0.50	0.79	0.54	1.22	1.73	1.26	86.13	76.91	85.69
	Nodule				1.25	2.79	1.73	*92.40*	68.21	86.85

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Effect of potassium nutrition (g/m2) on leaf water potential (Ψw), osmotic potential (Ψs), and pressure potential (Ψp) in four cotton cultivars

	Cultivar	KCl				K_2SO_4			
		K_0	$K_{6.25}$	$K_{12.5}$	$K_{25.0}$	K_0	$K_{6.25}$	$K_{12.5}$	$K_{25.0}$
Ψ_w	CIM-448	1.68	1.78	1.82	1.87	1.66	1.74	1.80	1.87
[-MPa]	CIM-1100	1.67	1.77	1.80	1.83	1.66	1.72	1.76	1.83
	Karishma	1.64	1.71	1.75	1.79	1.59	1.60	1.70	1.76
Ψ_s	CIM-448	2.28	2.40	2.49	2.59	2.29	2.42	2.54	2.66
[-MPa]	CIM-1100	2.36	2.49	2.60	2.68	2.38	2.49	2.60	2.73
	Karishma	2.13	2.27	2.34	2.43	2.13	2.29	2.38	2.52
Ψ_p	CIM-448	0.60	0.62	0.67	0.72	0.63	0.68	0.74	0.79
[MPa]	CIM-1100	0.69	0.72	0.80	0.85	0.72	0.77	0.84	0.90
	Karishma	0.49	0.56	0.59	0.64	0.54	0.63	0.68	0.76

Parvex et al., 2004

Influence of soil moisture and potassium on vegetative growth of faba bean. Relative growth rates were calculated from 0 over harvests at days 23, 28, 33 and 38 DAS in faba bean

Soil moisture	K(mM)	Relative growth rate (g dry weight increase g^{-1} dry weight day^{-1})	Total dry Weight (mg)	Specific leaf weight (mg cm^{-2})	Shoot/ root-ratio
Over 50% depletion	0.1	0.027 ±0.014	679	5.1	1.31
	0.8	0.051 ±0.003	981	4.4	1.45
	3.0	0.063 ±0.006	1146	3.4	1.71
Field capacity to 25% depletion	0.1	0.045 ±0.003	909	4.4	1.38
	0.8	0.062 ±0.007	1142	3.6	1.52
	3.0	0.101 ±0.012	1639	2.8	1.79

Bangalore: Long Term Manurial Experiment under rainfed conditions (Alfisol)(Rainfall: 900mm)Without Nutrient Input ?

Conclusions

- It can be concluded that excess K^+ in the leaf partially protects photosynthesis that deleterious effects of water stress.
- The protective effect appears to be mediated by extracholoroplantic K^+ in the plant cells, possibly acting on chloroplast photosynthesis through the mechanism of a K^+/H^+ transport system.
- Stomatal closure in water stress conditions is related with K^+ transport and also associated with high proline content of the plant parts.
- Thus potassium is needed at high concentrations inside the plants from early stages of vegetative growth phase.
- However, external K application to different crops should be recommended depending upon soil status of exchangeable and reserve K and crop K requirements.

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Conclusions

•However, in India research information on optimum K nutrition in water stress management in rainfed agriculture is rather meagre despite of larger rainfed area.

• Acidic red and lateritic soils, shallow black soils, light textured alluvial soils, arid soils etc in rainfed regions of India are K deficient, yet K application is minimal or absent.

•Therefore, it is suggested to take up studies on K impacts in coping up of intermittent droughts particularly K deficient regions in rainfed agriculture.



Thank You Very Much

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